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ABSTRACT

The objectives of this study were to examine some variations in the structure of those abilities generally considered to constitute mechanical aptitude and to focus attention on the problem of comparing factorial structures arising in different cultural groups. The sample was composed of 172 boys, aged 12 to 14, from 5 separate Canadian communities. Cultural environment was assessed by a questionnaire administered to the boys, and mechanical aptitude was measured through the use of a battery of 8 standardized tests. The results of the study suggested that extensive differences exist in the patterning and levels of ability among groups of Canadian boys from diverse cultural environments. (PS)

THE STRUCTURE OF MECHANICAL APTITUDE IN SEVERAL CULTURAL ENVIRONMENTS

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Paper presented at the Annual Meeting of the Canadian Psychological Association, June, 1972. Montreal, Canada.

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In this paper I propose to examine some variations in the structure of those abilities generally considered to constitute mechanical aptitude, and to focus some attention upon the problem of comparing factorial structures arising in different cultural groups.

Factor analysis has resulted in the subdivision of intelligence into several main groups of abilities, however factor analysts have emphasized that factor patterns depend not only upon the variables measured, but upon the method of analysis used and the nature of the group or groups being studied. Several studies (Lesser, Fifer and Clark, 1965; Irvine, 1969; MacArthur, 1969; Vernon, 1969) have shown that factor patterns as well as absolute levels of abilities may be expected to vary as a function of exposure to varying cultural environments. This observation was forecast almost twenty years ago when Ferguson (1954) provided a theoretical framework linking the development of abilities and learning theory.

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An examination of ability patterns is especially relevant to the study of mechanical aptitude since in Western groups it has been found to be a composite of several abilities. When broadly defined as an overall proficiency for occupations of a mechanical type Vernon (1950) has pointed out that it involves general intelligence, spatial ability, mechanical information and comprehension, and relevant manual dexterity and motor skills.

However, just as one might question the cross-cultural application of constructs such as "intelligence", so it might be argued that mechanical aptitude cannot be used to describe patterns of abilities in cultures of varying technological sophistication. Berry (1971) for example, has strongly criticized the employment of constructs developed by Western psychologists within their own culture in societies where qualitative differences in cognitive competence may reasonably be hypothesized to exist.

It is not my intention to argue for mechanical aptitude as a psychological universal. In fact it is implicitly recognized as the product of a technologically sophisticated culture, and that mechanical tests which may be valid in one culture need not necessarily be valid in another. Similarly, the means of describing

inter-relationships between variables in terms of common factors is seen as being subject to the same limitations.

It is necessary to emphasize though, that in order for the individual to adapt to and function successfully within a society becoming rapidly more technologically advanced, certain abilities are essential. As Vernon (1969) has pointed out, obviously a kind of intelligence that includes the manipulation of abstract numerical and verbal symbols is a prerequisite. Likewise, the kinds of skills entailed by mechanical aptitude must be developed if the individual is to perform successfully in occupations involving the use of tools and machinery.

My principal objective in this study was to establish whether the performance of several groups of Canadian Indian children on a battery of tests assumed to measure mechanical aptitude could usefully be described in terms of common factors. It was also hoped to discover whether comparable environmental conditions relevant to the development of mechanical skills were open to assessment across the several groups. The attempt to meet such objectives involved the application of a pooling procedure to the data in an effort to establish the actual degree of similarity of factors deriving from the different culture groups.

Design of the study

172 boys aged from twelve to fourteen were subjects for the present study. They came from three Indian communities (Morley, Alberta; Cluny, Alberta; Bella Bella, B.C.), a Metis community near Lac la Biche, Alberta, and from a Calgary junior high school. All available boys in the age range were tested in each native community and were selected irrespective of grade level achieved at school. A considerable range of acculturation is represented by the communities sampled, together with a diversity of language background, economy and cultural heritage.

The majority of tests used were unspeeded and required little verbal explanation. The total battery consisted of:

Raven's Progressive Matrices (1938)
Paper Formboard (Open-ended modification)
MacQuarrie Test of Mechanical Ability (1923)
Mill Hill Vocabulary Scale, Junior set A
Meccano model construction
Tool Knowledge test
Test of mechanical information
Test of mechanical comprehension

Cultural environment was assessed by questionnaire administered to the boys. The principal variables included were socioeconomic status (paternal employment), mechanical objects and tools in the home, mechanical operations performed, relevant hobbies and interests, language background and vocational interests.

The data from each sample were analyzed independently by the principal components method followed by varimax rotation, and resulting factor patterns compared by visual inspection. A pooling procedure outlined by Evans (1970) was then applied by combining the data from all groups and treating it as if it came from a single sample. This is essentially a method for dealing with questions concerning differences between the means of the groups and those concerned with structure simultaneously.

The total correlation matrix was analyzed by the principal components method, and varimax rotation applied with eigen values specified greater than unity. The final rotation was limited to six factors considered psychologically meaningful. Emergent factors are thus dependent upon differences between group means as well as within-group variation.

Estimated factor scores were then computed for all subjects in all groups simultaneously, using the total group means and standard deviations. These were then separated for each of the five culture groups and compared by analysis of variance. Because both means and variances of factor scores are compared, it is possible to separate those factors exhibiting much inter-cultural variation from those showing little.

Results and discussion

When the principal components analysis and subsequent varimax rotation was applied to each culture group independently, there were obvious differences in factor patterns. A general factor emerged in four groups, as did a clearly defined verbal factor, however dexterity appeared in three groups and the background variables showed little apparent consistency in their loadings from group to group. Comparisons of factors across groups in terms of these independent matrices then, was made difficult by lack of consistency.

The application of the pooled between-groups analysis resulted in six factors showing a considerable range of variation across culture groups. When factor means were compared significant between-group differences appeared for all factors except factor I, with factor II notably showing the greatest variation between groups.

Interpretation of factors is complicated by the rather large number of variables included, together with the relative absence of mixed factor markers. Factors I, II and IV are considered most clearly defined, while the remaining factors loading extensively on background variables are only tentatively discussed in the absence of conclusive evidence in the available data.

The first factor, termed g for its high loading on Raven's Matrices, includes a large spatial element

as evidenced by high loadings for Paper Formboard and the spatial subscales of the MacQuarrie test. The fact that group mean differences for this factor were not significant bears out a main expectation of this research, namely that Indian children demonstrate a superior mechanical-spatial ability relative to verbal ability, especially when a somewhat culturally-reduced battery of tests is employed.

The most extensive between-group differences were apparent for the second factor. The single high loading of Vocabulary and also the Parents English measure suggests that the type of skill represented by this factor is mediated by English. It therefore seems reasonable to interpret this as verbal facility. Notably, Calgary and Bella Bella, both monolingual English-speaking groups scored higher than the other groups but did not significantly differ from each other.

Factor IV is identifiable as Dexterity on the basis of its loadings on the three MacQuarrie subtests Tracing, Tapping and Dotting. There were no significant pair-wise differences for this factor.

The three remaining factors are more difficult to interpret since they straddle background variables. Factor V has been termed Age and showed no pair-wise mean differences across groups. Factors III and VI are most clearly distinguished by the high loadings of

Ownership of a bicycle and Mechanical hobbies on VI, and the loadings of Mechanical magazines and Knowing someone mechanically skilled on III. However several variables load on both and the naming of these factors respectively Background and Activities is to a large extent conjectural. Between-group differences were not extensive for the first of these factors, but the Calgary group was superior to all others on factor VI.

Conclusions and Implications

The results of this study suggest that extensive differences exist in the patterning and levels of ability among groups of Canadian boys from diverse cultural environments. It has not been my intention so much to present this finding as definitive, as to suggest that the method of analysis employed in this study may have useful application more generally in cross-cultural research.

The initial lack of factorial congruence when independent matrices from each culture group were examined calls into question the practice of identifying factors by visual inspection and attempting to compare them cross-culturally. An alternative approach is to employ the type of pooling procedure utilized in this study. However if such procedures are to produce definitive results the problems of sampling and choice of variables

already discussed will have to be given careful attention.

This study presents substantial evidence that among the diverse groups studied, Indian and Metis boys show comparable general mechanical ability to that of white children of a similar age. The extensive differences found for the verbal factor, together with its high correlations with language and socioeconomic variables suggest that achievement differences favoring white children are mediated by facility in English to a large extent. The immediate educational implications of this are clear.

Other cross-cultural factorial studies (e.g. Vernon, 1969; Irvine, 1969) have found that while the general and major group factors of Western psychologists typically emerge, specific factors that differ markedly between cultures also appear. While recognizing that the g factor is culturally loaded, Vernon has justified his study of "intelligence" cross-culturally by pointing out that the general factor always emerges from a wide range of varied tests. At the same time he stresses that evident factor patterns depend upon the nature of the groups studied. To the same extent, at least, it appears that cross-cultural studies of mechanical aptitude are justifiable.

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TABLE 1

VARIMAX FACTOR MATRIX FOR POOLED DATA

Variable	Factor I	II	III	IV	V	VI
Raven's	76	17	07	19	11	04
Meccano	39	15	-03	23	03	40
Tool Knowledge	39	47	21	33	27	25
Mech. Comp. 1	57	32	22	-15	17	07
Mech. Comp. 2	50	30	15	-08	12	15
Paperformboard	80	03	08	22	-06	-03
Mech. Know.	40	61	12	05	24	18
Tracing	18	01	27	66	07	-22
Tapping	25	20	-04	63	23	21
Dotting	07	01	-00	82	-01	05
Copying	67	26	11	25	-11	02
Location	54	23	-01	41	12	22
Blocks	71	17	-03	17	09	-00
Pursuit	43	14	10	48	05	05
Vocabulary	27	73	15	22	18	-11
Age	07	-10	05	09	72	02
Grade	35	46	25	21	54	09
Employment	20	72	12	02	10	05
Hobbies	06	-05	20	-05	-01	72
Bike	15	39	-16	03	-29	42
Magazines	07	06	61	03	-26	18
Mech. set	00	-03	34	-06	-45	03
Operations	-02	11	54	20	18	50
Tools	21	38	48	15	06	31
Tool Place	15	40	25	-00	18	14
Know Someone	15	13	62	07	13	-10
Par. English	-02	69	21	08	-18	-32
Job Pref.	-37	21	-08	03	20	-15
Factor Content	g	v	back-ground	dext-erity	age	activ-ities

*Decimal points omitted

TABLE 2

FACTOR MEANS AND STANDARD DEVIATIONS ACROSS GROUPS

Factor	I : g		II : verbal		III : mechanical background		IV : dexterity		V : age		VI : mechanical activities	
Group	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd
Bella Bella	-.21	.88	.59	.77	-.53	.91	-.10	1.02	-.45	.77	-.49	.90
Cluny	.19	.83	-.90	.88	.24	1.07	-.20	1.33	.25	.99	-.08	.89
Calgary	.29	1.16	1.06	.49	.01	.99	.03	.83	-.02	.99	.80	1.06
Morley	-.29	.94	-.64	.64	-.16	.86	-.22	.90	-.09	.89	-.22	.89
Lac la Biche	.02	1.04	-.10	.71	.37	.94	.38	.84	-.22	1.15	-.08	.82